



#4/1-16-02  
Bade  
PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Daping CHU

Group Art Unit: 2133

Application No.: 09/866,781

Filed: May 30, 2001

Docket No.: 109677

For: MEMORY DEVICE

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CLAIM FOR PRIORITY

Director of the U.S. Patent and Trademark Office  
Washington, D.C. 20231

Sir:

The benefit of the filing date of the following prior foreign application filed in the following foreign country is hereby requested for the above-identified patent application and the priority provided in 35 U.S.C. §119 is hereby claimed:

British Patent Application No. 0013232.4 filed May 31, 2000.

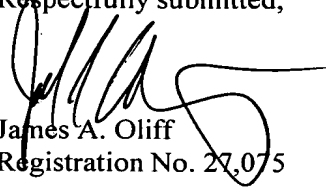
In support of this claim, a certified copy of said original foreign application:

  X   is filed herewith.  
       was filed on        in Parent Application No.        filed       .  
       will be filed at a later date.

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It is requested that the file of this application be marked to indicate that the requirements of 35 U.S.C. §119 have been fulfilled and that the Patent and Trademark Office kindly acknowledge receipt of this document.

Respectfully submitted,

  
James A. Oliff  
Registration No. 27,075

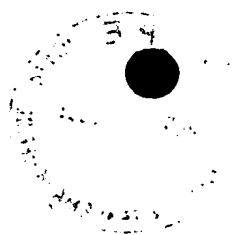
Joel S. Armstrong  
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JAO:JSA/kaf

Date: August 30, 2001

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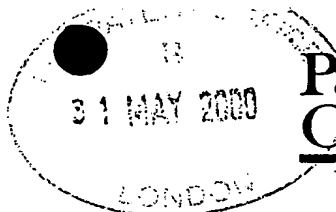
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Signed

Dated

6 August 2001

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APPLICATION NO.: 09/866,781  
FILED: May 30, 2001  
FOR: MEMORY DEVICE  
ATTORNEY DOCKET NO.: 109677



# Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

## 1. Your reference

GBP13080A

## 2. Patent application number

(The Patent Office will fill in this part)

0013232.4

31 MAY 2000

## 3. Full name, address and postcode of the or of each applicant (underline all surnames)

Seiko Epson Corporation  
4-1, Nishishinjuku 2-chome  
Shinjuku-ku, Tokyo 163-0811  
Japan

Patents ADP number (if you know it)

712331003

If the applicant is a corporate body, give the country/state of its incorporation

Tokyo, Japan

## 4. Title of the invention

Memory Device

## 5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

Miller Sturt Kenyon  
9 John Street  
London WC1N 2ES  
United Kingdom

Patents ADP number (if you know it)

07395486001

## 6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country

Priority application number  
(if you know it)

Date of filing  
(day / month / year)

## 7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing  
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## 8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

Yes

- a) any applicant named in part 3 is not an inventor, or
  - b) there is an inventor who is not named as an applicant, or
  - c) any named applicant is a corporate body.
- See note (d))

# Patents Form 1/77

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Description	5
Claim(s)	2
Abstract	1
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Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (Patents Form 7/77)

Request for preliminary examination and search (Patents Form 9/77) 1

Request for substantive examination (Patents Form 10/77)

Any other documents (please specify)

11. I/We request the grant of a patent on the basis of this application.

Signature

Date

Miller Sturt Lee

31st May 2000

12. Name and daytime telephone number of person to contact in the United Kingdom C M Sturt 020 7242 5974

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## Memory Device

The present invention relates to a memory device for data storage and in particular the invention relates to a memory device which makes use of the piezoelectric effect.

Ferroelectric materials, as a sub-set of piezoelectric materials, can exhibit a non-volatile, bi-stable internal polarisation. The state of polarisation is established by the application of a voltage between opposing surfaces of the material. Having applied a sufficiently large voltage to internally polarise the material, it ought subsequently to be possible to determine the direction of polarisation - which can be used as a binary indicator, whereby the material can act as a data storage medium. However, a problem arises in that the data read operation is destructive of the data. Specifically, the read operation would consist of applying a voltage to set the polarisation in a specified direction. If the polarisation is already in that direction no charge exchange is required. However, if the polarisation is in the opposite direction a relatively large amount of charge exchange is required to establish the specified direction of polarisation. Thus, the previous direction of polarisation can be judged according to the high or low (zero) level of charge exchange required to establish the specified polarisation.

It is an object of the present invention to provide a memory device which makes use of the internal polarisation of a ferroelectric material for data storage and in which a non-destructive data read operation can be undertaken. It is another object of the present invention to provide a method of data storage and retrieval which makes use of the internal polarisation of a ferroelectric material and in which a non-destructive data read operation can be undertaken.

According to a first aspect of the present invention there is provided a memory device comprising a layer of piezoelectric material and a layer of ferroelectric material clamped

together such that a voltage applied to one layer results in a voltage being generated across the other layer. Preferably, the piezoelectric material is implemented as a ferroelectric material.

According to a second aspect of the present invention there is provided a method of data storage and retrieval comprising the steps of: providing a layer of ferroelectric material, providing a layer of piezoelectric material, clamping the two layers together, storing data by internally polarising the ferroelectric material in one of two stable directions in accordance with the data to be stored, and retrieving stored data by applying a non-polarising voltage to one layer and detecting a resultant voltage from the other layer. Preferably, the step of providing a layer of piezoelectric material comprises the step of providing a ferroelectric material as that piezoelectric material.

Embodiments of the present invention will now be described in more detail, by way of further example only and with reference to the accompanying drawings, in which:-

Figure 1 illustrates the principle of operation of a piezoelectric device which acts as a voltage amplifier;

Figure 2 is a diagrammatic representation of data storage modes in a memory device according to one embodiment of the present invention;

Figure 3 is a diagrammatic representation of a multi-cell memory device according to another embodiment of the present invention;

Figure 4 illustrates a data read operation for a single cell memory device; and

Figure 5 illustrates the application of a conventional addressing scheme to a matrix memory device according to the present invention.

A description of the principle of operation of a piezoelectric device acting as a voltage amplifier will now be given, with reference to figure 1. As illustrated in figure 1, two layers (1, 2) of piezoelectric material are confined between two clamping members (3, 4). The voltage associated with the first layer (1) of piezoelectric material is referenced as  $V_1$ , it's



thickness as  $d_1$  and its inherent characteristics as  $\epsilon_{r1}$  and  $d_{33,1}$ . Similarly, the voltage associated with the second layer (2) of piezoelectric material is referenced as  $V_2$ , it's thickness as  $d_2$  and its inherent characteristics as  $\epsilon_{r2}$  and  $d_{33,2}$ . Ideally,

$$\Delta d_i(E_i) \equiv d_i(E_i) - d_i(0) \approx d_{33,i} d_i(0) E_i \approx d_{33,i} V_i$$

Due to the external confinement of the layers,  $\sum \Delta d_i = 0$  and hence:-

$$V_2 = \pm (d_{33,1}/d_{33,2}) V_1$$

where the signs correspond to the parallel and anti-parallel polarisation between layers 1 and 2.

The device illustrated in figure 1 may be referred to as a ferroelectric amplifier, ferroelectric and piezoelectric effects being considered to co-exist.

As already noted, a relatively large voltage is required to change the direction of polarisation of the ferroelectric materials. Applying a relatively small voltage will not change the direction of polarisation. Thus, in the device illustrated in figure 1 applying a small voltage  $V_1$  will not change the polarisation of layer 1 but by reading the sign of the consequential output  $V_2$  (the magnitude of which is sufficiently small so as not to change the direction of polarisation of layer 2) the parallel or anti-parallel polarisation directions of layers 1 and 2 is immediately, and non-destructively, detected. Thus, considering the polarisation direction of one of the layers as a reference and arranging for the polarisation direction of the other layer to be changed to represent a binary indicator, a non-volatile memory device is provided in which non-destructive reading of the binary indicator is performed simply by phase comparison of the input and output read voltages. An example of the thus described basic cell is illustrated in figure 2.

In figure 2, the polarisation of the lower layer is used as the reference and the polarisation of the upper layer is used for data storage. As illustrated, the parallel polarisation condition has been associated with binary "1", input and output voltages being out of phase,

and the anti-parallel polarisation condition is associated with binary "0", input and output voltages being in phase.

A particular advantage of the memory device according to the present invention is that it is not easily affected by external disturbance. The displacement involved in the read out is internal and relative. It can be considered analogous to the optical mode of phonons. External disturbance, eg vibrations, is similar to the acoustic mode and has very little impact on the output.

From the foregoing description it will be appreciated that one aspect of the present invention resides in the use of the piezoelectric effect to read data from a memory cell. Specifically, the so-called reference layer of figure 2 can be implemented as a piezoelectric layer rather than a ferroelectric layer. Applying a voltage to the piezoelectric layer causes a contraction or expansion of the piezoelectric layer and a resulting change in the ferroelectric layer, which change is detectably dependent upon the direction of polarisation of the ferroelectric material. This can be considered as an in-phase only version of the embodiment of figure 2. Further, although clamping of the layers has been illustrated in terms of a physical confinement (constant distance), clamping of the layers is also to be understood as subjecting them to a constant force (stress) – for example. The requirement is that the change in one layer should act upon the other layer and not be lost externally.

The operation of a single memory cell has been described with reference to figures 1 and 2. For practical use it is desirable to provide an array of many cells. Such an array can readily be provided in accordance with the present invention. The basic cell requires three electrodes. These are identified by reference numerals 5, 6 and 7 in figure 1. That is, voltage  $V_1$  is applied between electrodes 5 and 6 and voltage  $V_2$  is measured between electrodes 6 and 7. Although a common electrode 6 is illustrated, it would of course be feasible to use two respective separate electrodes, for the upper and lower layers, in place thereof. As shown in

figure 3, an array of cells is formed by providing a respective plurality of electrodes 5, 6 and 7. A plurality of elongate, parallel and spaced apart electrodes 5 are provided in one plane. A similar plurality of elongate, parallel and spaced apart electrodes 7 are provided in a parallel plane and a plurality of elongate, parallel and spaced apart electrodes 6 are provided in another parallel plane, between the other two planes. Further, the electrodes 5 and 7 are parallel to each other and vertically aligned whereas the electrodes 6 are perpendicular to electrodes 5 and 7. Individual memory cells are thus formed at each point of "intersection" or overlap of respective individual electrodes 5, 6 and 7.

As illustrated in figure 4, a comparator 8 is used to read each memory cell. Comparator 8 compares the sign, or phase, of the voltages  $V_1$  and  $V_2$  and the output can be taken directly as the binary value "1" or "0". It is a particular advantage of the present invention that the data content of the memory cell can be read using a simple comparator circuit.

The memory array explained with reference to figure 3, using a plurality of comparators as described with reference to figure 4, can be used to implement either an active or a passive matrix. Importantly, the resulting matrix can be addressed using conventional addressing techniques. The matrix connections for conventional addressing of a plurality of memory cells according to the present invention is depicted in figure 5.

The foregoing description has been given by way of example only and it will be appreciated by a person skilled in the art that modifications can be made without departing from the scope of the present invention.

### Claims

1. A memory device comprising a layer of piezoelectric material and a layer of ferroelectric material clamped together such that a voltage applied to one layer results in a voltage being generated across the other layer.
2. A memory device as claimed in claim 1, wherein the piezoelectric material is a ferroelectric material.
3. A memory device as claimed in claim 1 or claim 2, wherein a common electrode is provided between the two layers, an input electrode is provided on one of the layers and an output electrode is provided on the other of the layers, the input and output electrodes being disposed on opposite sides of their respective layers compared with the common electrode.
4. A memory device as claimed in claim 3, further comprising a comparator having respective inputs connected to the input and output electrodes.
5. A memory device comprising a plurality of devices as claimed in any preceding claim.
6. A memory device as claimed in claim 5, wherein the respective input electrodes are arranged parallel to each other in a spaced apart manner in a first plane, the respective common electrodes are arranged parallel to each other in a spaced apart manner in a second plane and the respective output electrodes are arranged parallel to each other in a spaced apart manner in a third plane, with the said planes being parallel to each other, the input and output electrodes being parallel with each other and the common electrodes being perpendicular thereto.

7. A method of data storage and retrieval comprising the steps of: providing a layer of ferroelectric material, providing a layer of piezoelectric material, clamping the two layers together, storing data by internally polarising the ferroelectric material in one of two stable directions in accordance with the data to be stored, and retrieving stored data by applying a non-polarising voltage to one layer and detecting a resultant voltage from the other layer.

8. A method as claimed in claim 7, wherein the step of providing a layer of piezoelectric material comprises the step of providing a ferroelectric material as that piezoelectric material.

9. A method as claimed in claim 8, comprising the steps of: internally polarising the piezoelectric layer implemented by a ferroelectric material in a reference direction, arranging for the storage of data by internally polarisation in the said one of two directions relative to the reference direction.

10. A method as claimed in any of claims 7 to 9, wherein the step of detecting the said resultant voltage comprises comparing the phase of the said resultant voltage with the phase of the said applied non-polarising voltage.

### Abstract

A memory device comprising a layer of piezoelectric material and a layer of ferroelectric material clamped together such that a voltage applied to one layer results in a voltage being generated across the other layer. The method of data storage and retrieval comprising the steps of: providing a layer of ferroelectric material, providing a layer of piezoelectric material, clamping the two layers together, storing data by internally polarising the ferroelectric material in one of two stable directions in accordance with the data to be stored, and retrieving stored data by applying a non-polarising voltage to one layer and detecting a resultant voltage from the other layer. Preferably, the piezoelectric material is implemented as a ferroelectric material.

Refer to Fig. 2

Fig. 1

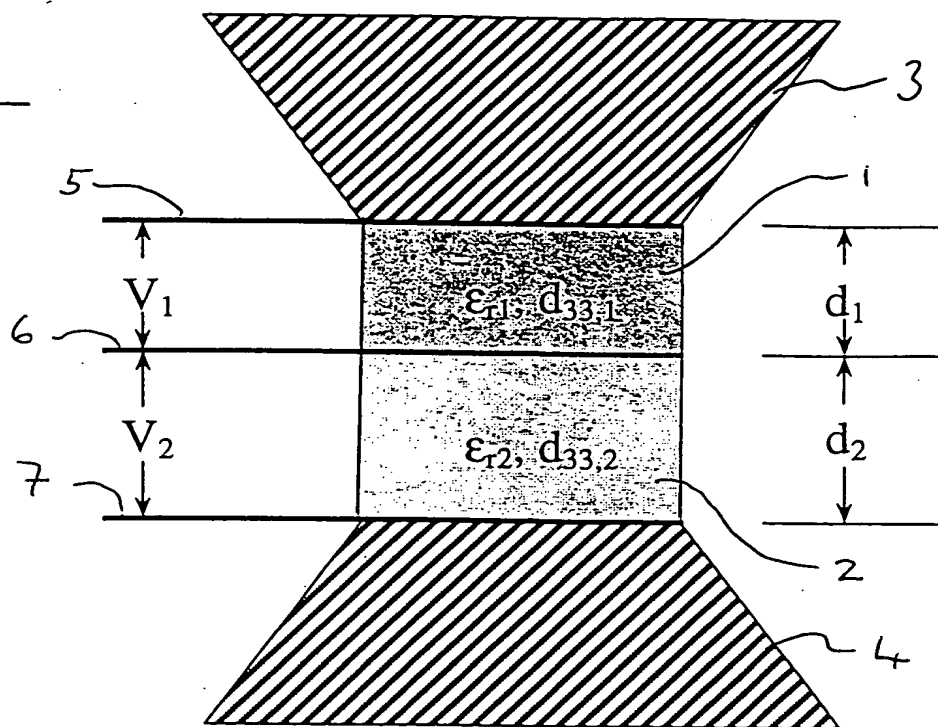


Fig. 2.

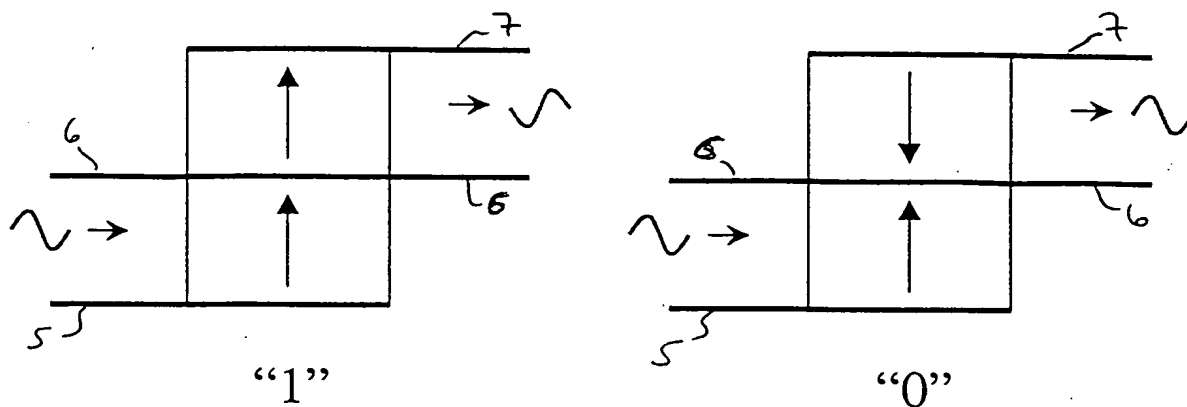






Fig. 3

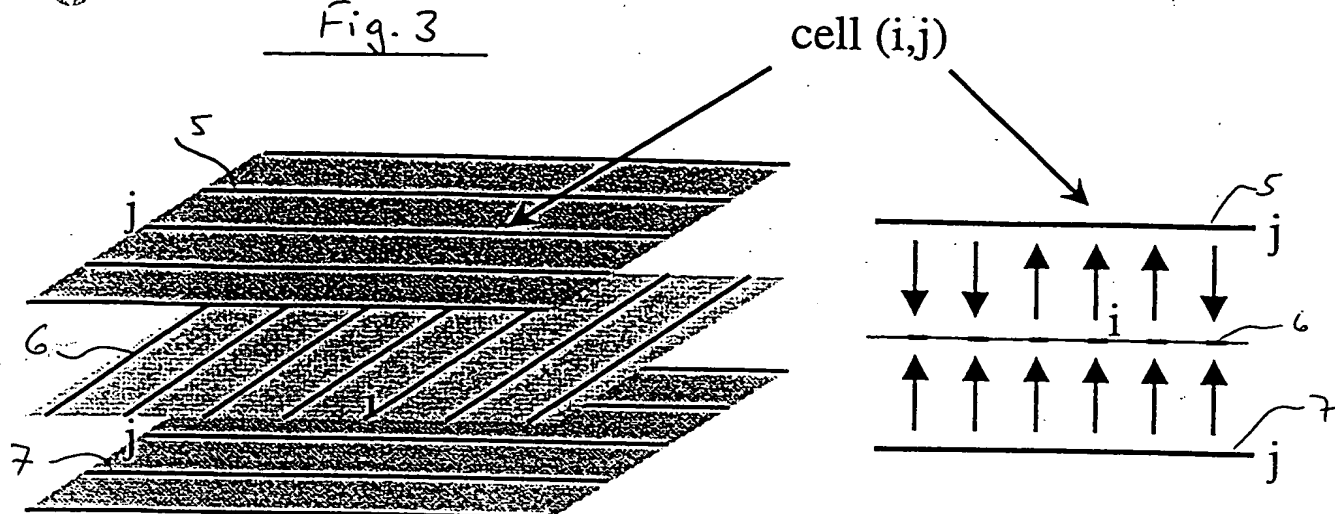


Fig. 4

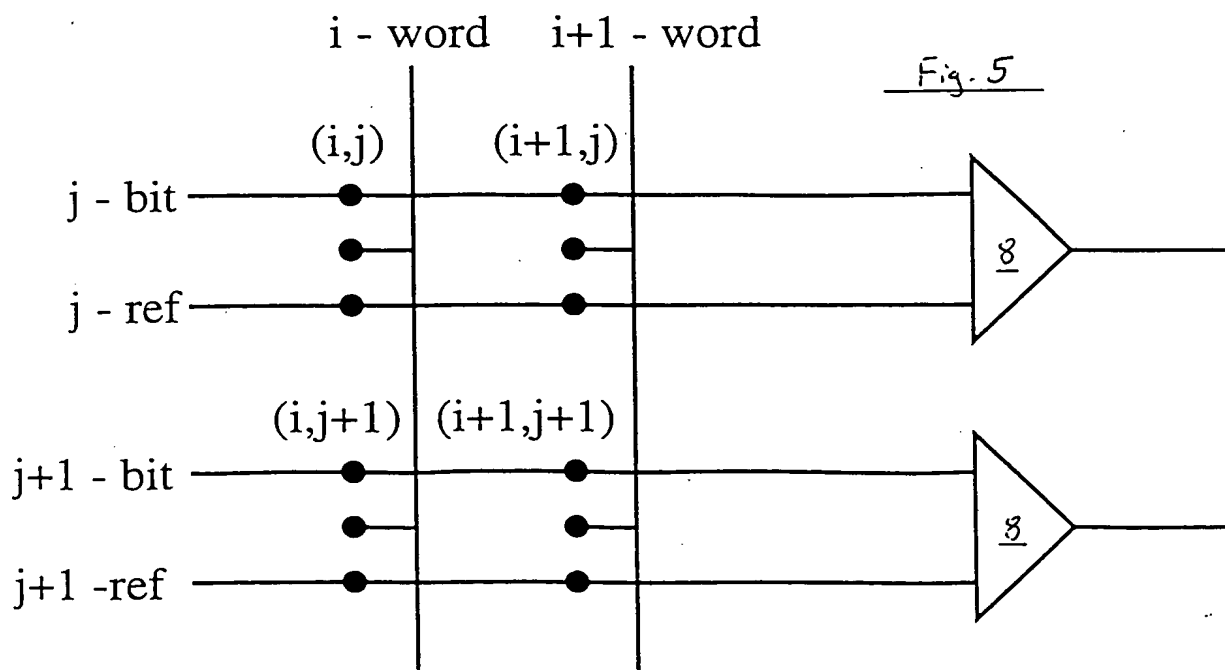
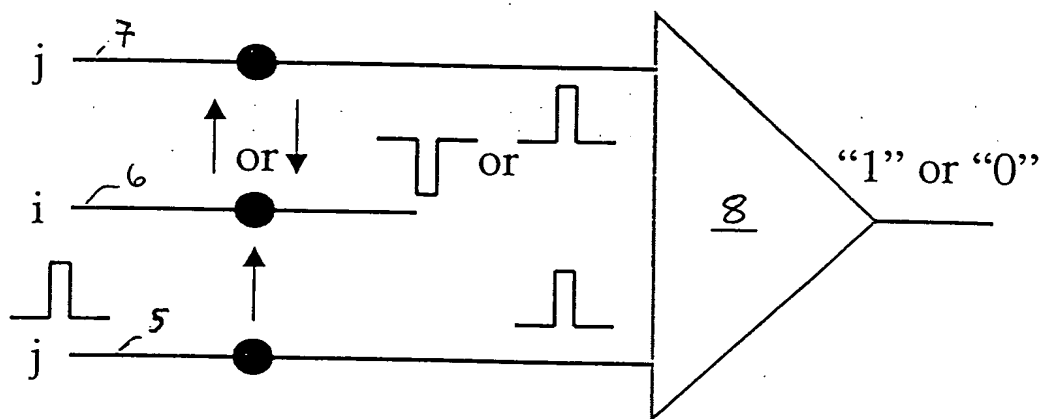


Fig. 5

